

# Myocardial atrio-venous junctions and extensions (sleeves) over the pulmonary and caval veins

## Anatomical observations in various mammals

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The myocardial fibres of the posterior wall of the atrio-venous junctions were examined in 35 large domestic mammals. In the majority of specimens a common pattern in the course and organization of the fibres could be observed. The most obvious features were the following: (1) a main circular fascicle surrounding the pulmonary trunks; (2) fibres encircling the atrio-venous junctions; and (3) myocardial sleeves extending along the veins, occasionally as far as the lung. The superior part of the left atrial wall was consistently thicker than the inferior section. Individual variations of this wall between the various trunks followed one of four patterns—vertical, oblique, horizontal or criss-crossed. Differences between mammal and human hearts were found regarding the number of pulmonary trunks, the presence of the oblique vein of the left atrium, and the extension of the myocardial sleeves on the caval vein. This extension on the caval vein continues over the end of the azygos vein in animals. The functional significance of the structures described in this study is discussed.

The presence of sleeves of atrial myocardium continuing over the pulmonary veins and venae cavae have been observed in various mammals and human hearts (Favaro, 1910; Brown, 1913; Papez, 1920; Auër, 1948; Los and Dankmeijer, 1956; Neill, 1956; Thomas, 1959; Klavins, 1963; Kosir, 1964; Carrow and Calhoun, 1964; Nathan and Eliakim, 1966). Although these sleeves are commonly neglected in anatomical textbooks and medical literature (Bourdelle, 1920; Bruni and Zimmerl, 1951; Sisson, 1953; Miller, Christensen, and Evans, 1964; May, 1964), they may perhaps be of functional importance. Previous studies in dogs (Eliakim, Stern, and Nathan, 1961) and humans (Nathan and Eliakim, 1966) disclosed that the atrial wall around the superior veins was thicker and the sphincter-like arrangement of the fibres was generally more distinct around the superior veins. It was also observed that the myocardial sleeves of the superior veins usually extended further towards the lung than did the sleeves of the inferior veins.

In the present work, hearts of large mammals were studied with the hope that their dissection might contribute more anatomical details about the atrio-pulmonary and atrio-caval vein junctions, in order to permit a better understanding of the functions of these structures.

### MATERIAL AND METHODS

The hearts of 35 animals—17 sheep, 9 cattle, 5 pigs, 2 donkeys, 1 horse, and 1 camel—of various ages, both male and female, were dissected for the present study. The heart, pulmonary vessels, and part of the lungs were removed together in all cases. The anterior caval vein was cut above the opening of the azygos vein and the posterior caval vein was cut at the level of the diaphragm. The atria were separated from the ventricles at the level of the atrioventricular sulcus, so that they could be examined from both the inner and outer aspects. Using a micrometer caliper with a ratchet stop, the thickness of the posterior wall of the left atrium was measured at a constant pressure. A vernier permitted readings with an accuracy of 0.1 mm. The measurements were made midway between the left superior pulmonary vein and the right pulmonary vein, and at the midpoint between the left inferior pulmonary vein and the right pulmonary vein. Additional measurements were made of the length of the myocardial sleeves on the pulmonary and caval veins.

Pericardium, fascia, vessels, and nerves were cleaned from each specimen in order to expose and follow the myocardial fibres as clearly as possible. To facilitate the dissection, cotton was stuffed into the atria and rubber tubes were placed in the vessels. The natural colour of the myocardium was better retained in fresh specimens, while for following the course of the fibres and fascicles, formalin fixation was more satisfactory.

## OBSERVATIONS AND DESCRIPTIONS

Although the myocardial patterns of all the specimens studied differed from one another in some aspects, it was possible to recognize a more or less constant common basic pattern in the arrangement of the myocardial fibres (Figs 1 and 2).

Generally, there were three main venous trunks originating from the left atrial wall—two left pulmonary veins, the superior (L.S.P.V.) and the in-

ferior (L.I.P.V.), and one single right pulmonary vein (R.P.V.). In some cases, two right pulmonary veins, the superior (R.S.P.V.) and the inferior (R.I.P.V.), were present. The common basic pattern of the fibre arrangements (Fig. 1) was formed by a main circular fascicle (a, a', a'', a''') running peripherally around the openings of all

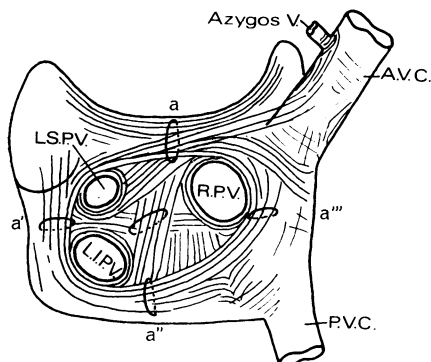


FIG. 1. Schematic representation of the common pattern of the superficial myocardial fibres of the left atrium. This fibre arrangement consists of a main circular fascicle (a, a', a'', a''') running peripherally around the openings of all pulmonary venous trunks. A.V.C.=anterior vena cava; P.V.C.=posterior vena cava; R.P.V.=right pulmonary vein; L.S.P.V.=left superior pulmonary vein; L.I.P.V.=left inferior pulmonary vein.

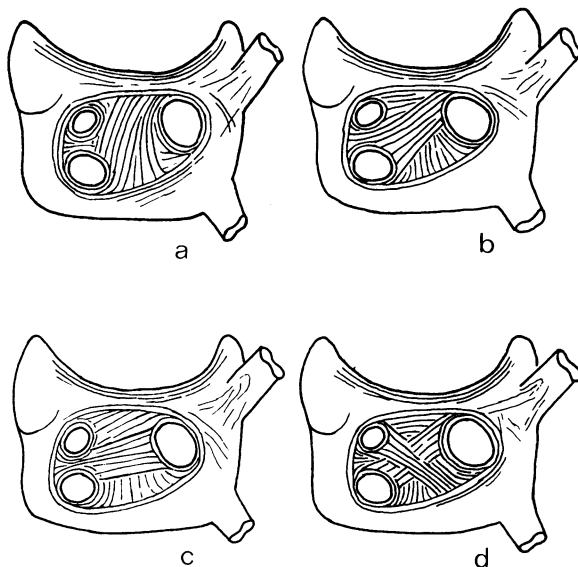


FIG. 2. Schematic representation of the area between the three pulmonary trunks. Note the various predominant patterns: (a) vertical, (b) oblique, (c) horizontal, (d) criss-crossed oblique.

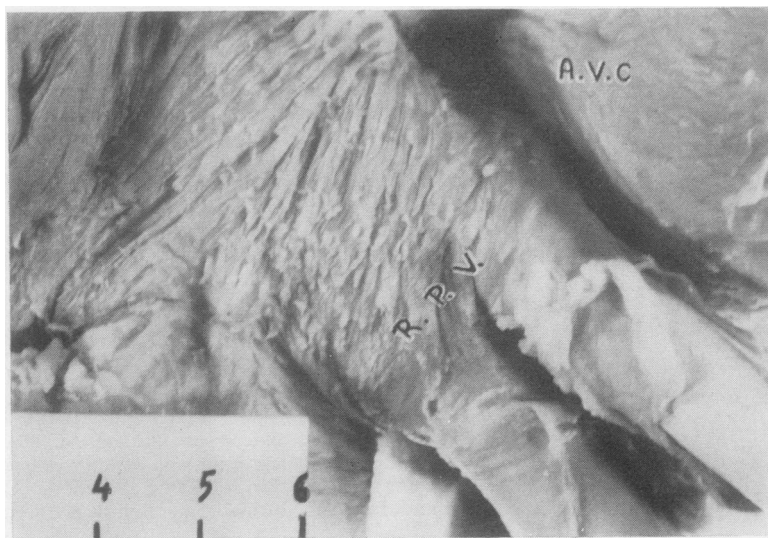


FIG. 3. Camel. Fibres leaving the main fascicle turn around the opening of the right pulmonary trunk (R.P.V.), forming a conspicuous sphincter-like structure, which continues over the vein as a myocardial sleeve, beyond the division of the vein.

three pulmonary venous trunks. The upper part of the main fascicle (a) extended horizontally above the R.P.V. and the left superior pulmonary trunk (Fig. 9a, b). This part of the fascicle consisted of fibres coming from the right auricle, from the wall of the anterior vena cava, and from the right atrium. Fibres extending between the two auricles (interauricular fascicle) accompanied and partially mingled with the main circular fascicle.

After passing over the L.S.P.V., the main fascicle turned downwards and proceeded to the left of the L.I.P.V. (a'). Fibres descending from the left auricle joined this part of the main circular fascicle.

After passing under the L.I.P.V., the fibres continued towards the right (a''), then turned upwards (a''') to encircle the R.P.V. They passed between this vein and the anterior vena cava to complete the circle by joining fibres of the first segment (a). Many fibres of the main circular fascicle inserted into or arose from atrio-ventricular fibrotic rings which lay deep to the basic fascicle.

In the vicinity of the pulmonary veins, fibres left the main fascicle and turned around the openings of these veins, forming sphincter-like structures (Figs 1, 2, 3, and 7). Some of these fibres extended to a greater or lesser degree over the veins, contributing to the formation of myocardial sleeves which covered the venous walls to a variable distance (Table) (Figs 4, 5, 6, 8, and 9).

Other fibres passing from the atrial wall also contributed to the formation of these myocardial sleeves (Fig. 4). They ran in longitudinal, oblique or spiral directions. Some of these fibres travelled along the veins for a variable distance, then arched back towards the atrium, thus forming characteristic loops (Fig. 4).

The length of the myocardial sleeves was not constant. Sometimes they extended as far as the

hilus of the lung or into the lungs themselves. The free borders of the muscular sleeves were generally oblique (Figs 5 and 6). Thus, the distance to the atrium was different from various points on the border of the sleeves. Our measurements of the sleeve lengths were taken from the most distant points. When a pulmonary vein divided, the sleeves could accompany either or both of the branches (Figs 3 and 4). In general, a small difference in the lengths of the sleeves, favouring the L.S.P.V., could be observed (Table).

Regarding the caval veins, the myocardial sleeve extending over the anterior was very conspicuous and could extend for more than 137 mm. (Figs 6 and 9a).

Over the posterior caval vein, such extensions were either absent or very small (Figs 5, 6, and 9a). In some specimens the sleeve of the anterior

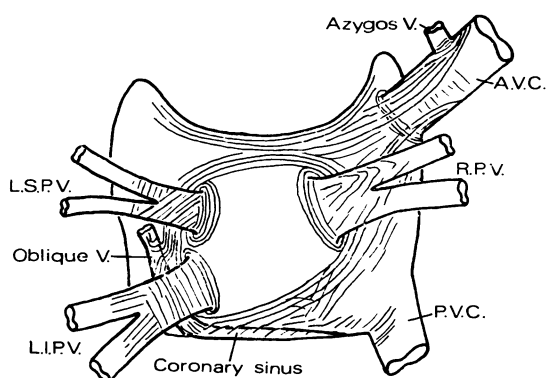


FIG. 4. Schematic representation of the three pulmonary trunks, the oblique vein, the anterior and posterior venae cavae and the azygos vein shows the various types of fibres (transverse, longitudinal, oblique, and loops) of the myocardial sleeves.

TABLE  
LENGTHS OF MYOCARDIAL SLEEVES AND THICKNESS OF THE ATRIAL WALL

Animals	No.	Range and Average	Length of Myocardial Sleeves (mm.)					Thickness of Atrial Wall (mm.)	
			R.P.V.	L.S.P.V.	L.I.P.V.	A.V.C.	P.V.C.	Area from L.S.P.V. to R.P.V.	Area from L.I.P.V. to R.P.V.
Sheep .. .. .	17	Range Average	5-16 10	7-16 10.5	6-16 10	19-42 29	5-12 6	0.5-1.8 1.2	0.6-1.2 0.9
Horse .. .. .	1	Range Average	— 12	— 13	— 9	— 76	— 13	— 3	— 2.5
Donkey .. .. .	2	Range Average	12-16 14	10-13 11.5	6-15 10.5	25-36 30.5	3-10 6.5	1.7-2.1 1.9	1.5-1.7 1.6
Camel .. .. .	1	Range Average	— 11	— 12	— 8	— 42	— 10	— 4.2	— 2.7
Cattle .. .. .	9	Range Average	21-29 25	33-40 38	29-37 34	125-142 137	27-37 35	2.18-5.53 3.7	1.85-3.42 2.4
Pigs .. .. .	5	Range Average	8-12 9.6	8-12 10	5-7 6	15-25 20	4-15 8	1-1.2 1.1	0.8-0.9 0.85

caval vein was also seen covering the end of the azygos vein to some extent (Fig. 6).

The oblique vein of the left atrium (vena obliquea atrii sinistri) was nearly constantly found. This vein distinctly descended on the left atrium to the left of the left pulmonary trunks (Fig. 9a). After turning under the L.I.P.V. it entered the coronary sinus (Fig. 4). Myocardial fibres leaving the main fascicle from segment (a) were seen partially extending over the vein (Fig. 9b) close to the L.S.P.V. They passed over the oblique vein in bundles of fibres, running on the anterior and posterior aspects of the vein. The bundles divided in ascending and descending fibres. These fibres joined other fibres descending laterally from the vein itself to partially ensheath the vessel (Fig. 9c). The coronary sinus was covered by myocardial fibres from a'' as classically described (Fig. 4).

In the central area between the three or four pulmonary trunks the superficial atrial fibres could be observed running in different directions and following various patterns (Fig. 2). The most frequently observed fibre directions were vertical

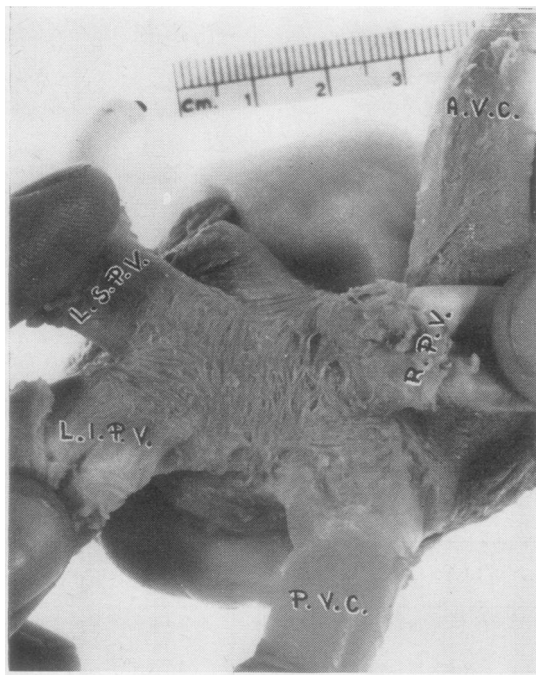


FIG. 5. Sheep. Predominant vertical direction of the fibres in the area between the three venous trunks. Note the extensive myocardial sleeve on the anterior vena cava (A.V.C.) and the absence of fibres on the posterior vena cava (P.V.C.).

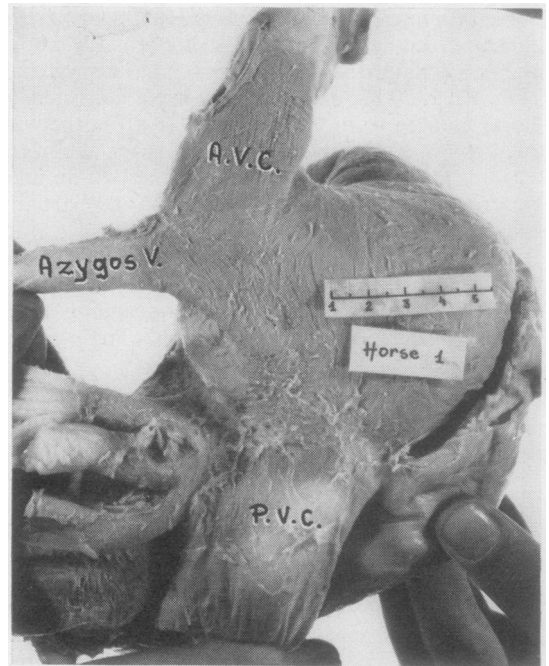


FIG. 6. Right superior aspect of the right atrium. The conspicuous extension of the myocardial sleeve over the anterior vena cava (A.V.C.) and its small extension over the posterior vena cava (P.V.C.) can be seen. An extension of myocardium over the end of the azygos vein is also evident.

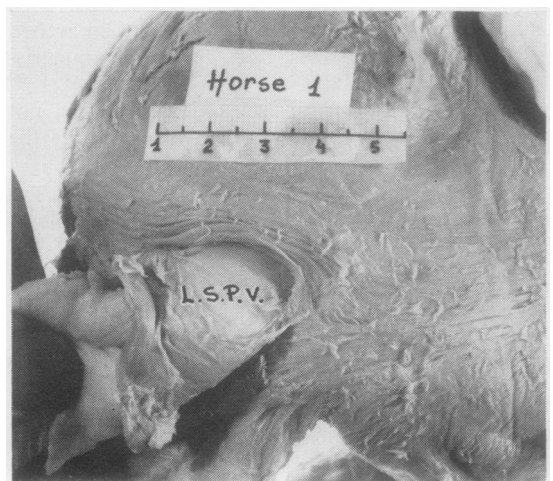


FIG. 7. (Same specimen as in Fig. 6.) Shows the very pronounced sphincter-like structure at the left superior pulmonary vein (L.S.P.V.).

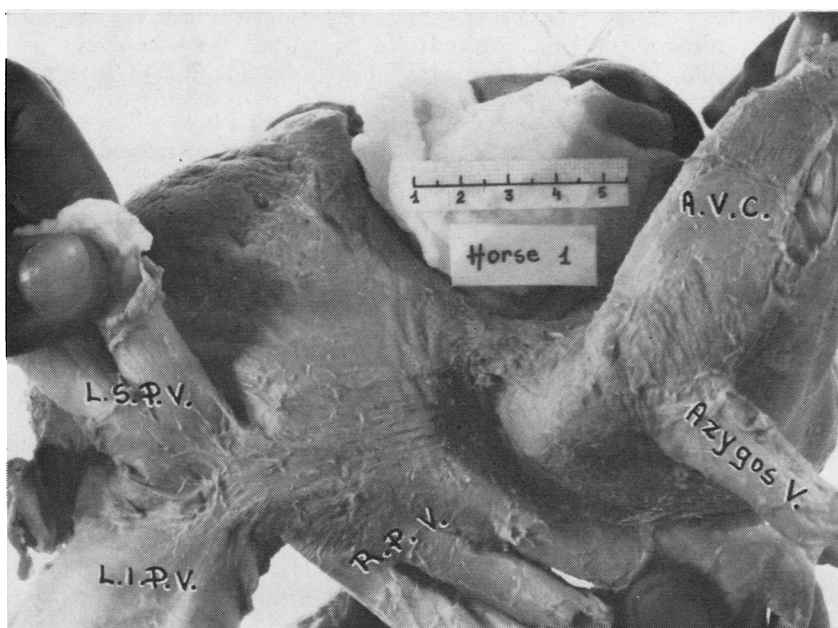


FIG. 8. (Same specimen as in Fig. 6.) The predominant direction of the fibres in the area between the three trunks is oblique in this specimen. It can be seen that a few fibres from this area continue on to the left inferior pulmonary vein (L.I.P.V.). The short right pulmonary trunk (R.P.V.) divides in this case into three branches.

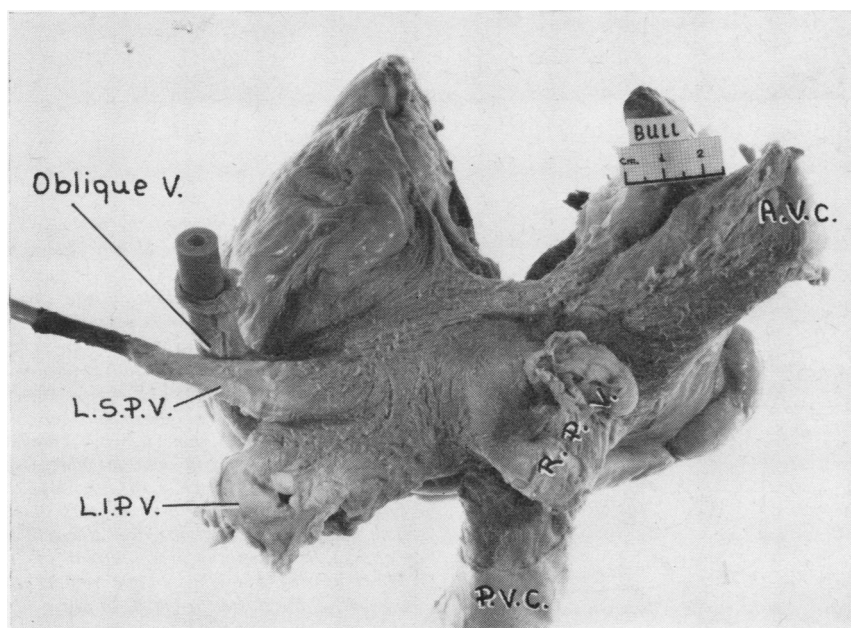


FIG. 9a. Legend on page 322.

(Figs 5, 9a) or oblique (Fig. 8). In some cases horizontal fibres were predominant (Fig. 2c), and in a few instances oblique fascicles criss-crossed each other (Fig. 2d). Occasionally, fibres were seen intermingling with each other, following no apparent pattern.

The results of the measurements showed that the atrial wall was not uniformly thick (Table). The upper part, particularly the area between the

L.S.P.V. and the R.P.V., was consistently found to be thicker than the lower part between the L.I.P.V. and the R.P.V. In some specimens the atrial wall in its lower parts, adjacent to the openings of the L.I.P.V. or the posterior vena cava, appeared devoid of muscle fibres. The atrial wall in this area was very thin and consisted only of endocardium covered by some connective tissue and pericardium.

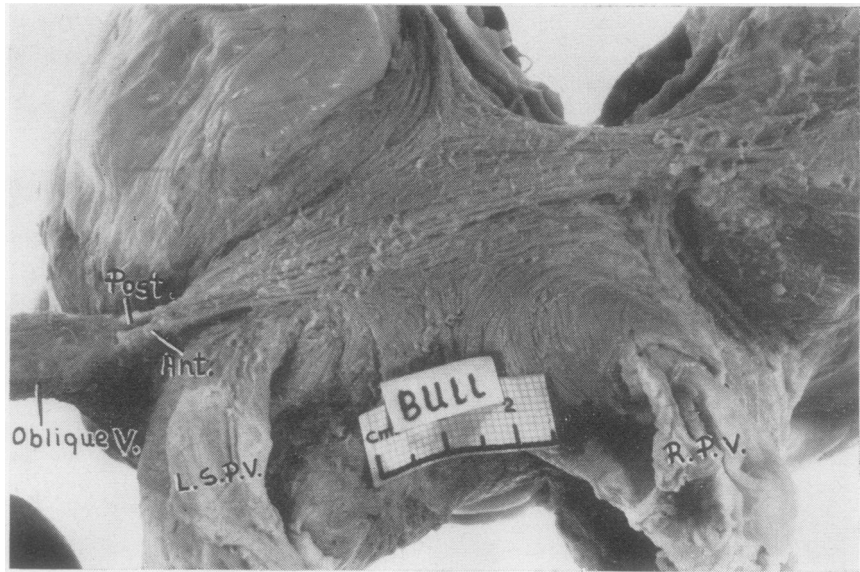


FIG. 9b.

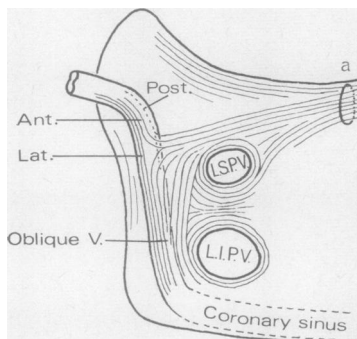


FIG. 9c.

FIG. 9. (a) General view of the superior aspect of a bull's heart. The oblique vein is clearly shown to the left of the left pulmonary trunks (L.S.P.V. and L.I.P.V.). The predominant fibre direction in the atrial area between all the pulmonary trunks is vertical. A conspicuous myocardial sleeve is seen on the anterior vena cava (A.V.C.), while only a small myocardial extension is present over the posterior vena cava (P.V.C.) (b) Closer view of the same specimen as shown in Fig. 9a with the left superior pulmonary vein (L.S.P.V.) deflected downward. It shows clearly the myocardial fibres leaving the upper part of the main fascicle (a) to pass over the anterior (Ant.) and posterior (Post.) aspects of the oblique vein. The course of these fibres over the vein is shown in Fig. 9c. (c) Schematic representation of the myocardial fibres passing over the oblique vein. The anterior (Ant.) as well as the posterior (Post. in dots) fibres divide over the vein as ascending and descending fibres. Another bundle of fibres (Lat.) is shown descending from the vein itself laterally and parallel to the anterior fibres.

The diameters of the bases of the three trunks generally had the same relative proportions. The biggest was the R.P.V., then the L.I.P.V., and the smallest was the L.S.P.V. However, in the cattle and the camel, the largest was the L.I.P.V., then the R.P.V., and the smallest the L.S.P.V.

#### DISCUSSION

From the present work it can be seen that in spite of the small anatomical differences in individual hearts and various species, a similar pattern in the course of the atrial fibres, as well as the atrio-ventricular pulmonary and caval vein junctions, was observed. This is nearly the same as what was found in human hearts (Nathan and Eliakim, 1966).

The main difference between the animal and human hearts was the number of pulmonary trunks. While in man there are generally four pulmonary veins (two left and two right), the animal hearts examined for this study usually had only three main trunks (two left and one right). This number of trunks was generally found in the sheep as well as the horse, donkey, and camel hearts dissected for this study. In the cattle, however, four trunks were usually seen, as in man. In some specimens a very short right pulmonary trunk covered by a conspicuous myocardial sleeve, which divided immediately into two or more pulmonary veins, aroused doubts about considering it as one or two veins coming from the atrium. This may explain the different descriptions found in the literature about the standard number of veins in each of the species (Bruni and Zimmerl, 1951; Sisson, 1953; May, 1964).

In the animals of the present study, as well as in humans (Nathan and Eliakim, 1966) and dogs (Eliakim *et al.*, 1961) previously studied, the left atrial wall was consistently thicker in its upper part. In addition, the atrial venous junctions were more conspicuous and the myocardial sleeves were longer on the superior than the inferior pulmonary and caval veins.

The fact that the oblique vein was frequently present in animals (Miller *et al.*, 1964) and infrequently present in man, is another difference to be noted. No mention of the relation of this vein to the myocardial fibres, as previously discussed, was found in the literature.

It may also be stressed here that the presence of myocardial sleeves over the azygos vein as an extension of the sheath of the caval vein was frequent in animals and rarely found in humans.

Regarding the functional significance of the

findings of the present work, it is difficult to draw conclusions other than those discussed in other works. The atrial pulmonary venous sphincters and sleeves were considered to have a *valve action* preventing reflux of blood during systole (Burch and Romney, 1954). This concept is supported by radiographic (Kjellberg and Olsson, 1954) and experimental (Little, 1960) observations. The contribution in the *regulation of the pulmonary venous pressure and blood flow* has also been attributed to the sleeves ensheathing the veins in physiological and experimental conditions (Eliakim and Aviado, 1961; Kuramoto and Rodbard, 1962, Smith and Coxe, 1951; Gilbert, Hinshaw, Kuida, and Visscher, 1958; Rudolph, Gootman, Golinko, and Scarpelli, 1961). Descriptions of *active expulsion of blood* from the veins into the atria, facilitating the filling of the atria, have also appeared in the literature (Carrow and Calhoun, 1964). Contractions of the sleeves were actually seen to precede the contraction of the atrium during systole (Hooker, McAllister, and Ellis, 1964; Carrow and Calhoun, 1964).

We cannot offer any interpretation of a functional significance for the varying patterns of myocardial fibres on the atrial wall.

Detailed anatomical studies of the heart and atrio-venous junctions may, perhaps, be of some help for many aspects, clinical and experimental, of modern cardiac surgery. Further physiological studies are needed to establish the full functional significance of the structures studied in this work and their variations.

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